Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

SCIENCE

FRIDAY, OCTOBER 21, 1910

CONTENTS

MSS. intended for publication and books, etc., intended for review should be sent to the Editor of SCIENCE, Garrison-on-Hudson, N. Y.

CONSERVATION OF THE PURITY OF SOILS IN CEREAL CROPPING

THIS seems to be the day of "conservation." Having suddenly caught the idea that our natural resources are rapidly being wasted through careless methods, and largely because of the intense desire of our people to accumulate riches, many of the best minds are concentrating their efforts toward husbanding natural resources. With the rapid increase in population and the numerous new desires which go with civilization the drain upon natural resources becomes apparent to every one. Almost every magazine and daily paper bears a message upon some new phase of conservation: As the conservation of human health and energy, conservation of forests, mines and water power; and the essentials of soil fertility; and there are even those who are crying for the conservation of capital, perhaps not unwisely.

The greatest asset of the human race is the earth and its products, and it is a view of the necessity of conserving a certain feature of crop productivity of the soil that I wish to bring before you. While we all talk freely of conservation, it must be recognized that there is no feature of it that is easy to carry out in a theoretically correct manner. Human interests and human understandings are so diverse that what is fact to one man is theory to another. In dealing with so simple a matter as the cropping of the soil to a particular crop, it is only when a great majority of our best educated agriculturists agree upon a feature, that it seems possible to get it accepted by the farming public, and often then it is only a comparatively small

number that actually carry out the work in a manner sufficiently effective to demonstrate the worth of the method.

Every man of normal mind honestly wishes the welfare of his race, and his nation in particular. It is nevertheless apparent that great difficulties must of necessity beset any attempt on the part of the state or the nation to conserve any one of its natural resources; for after all has been said, conservation is a biological problem. It is essentially impossible for the individual to actually place the nation or society at large as first in importance as against the actual and apparent necessities of self and family. It is all the more difficult because it is hard, because of the lack of facts, for the individual man to clearly distinguish actual necessities of individual and family life from apparent necessities and the actually necessary steps in work from the useless. Thus the collective desires of society for conservation must always meet strong opposition from individuals and classes of individuals. Any attempts to solve any of the great problems of the conservation or handling of resources which are possible of rapid development and exploitation, as, for example, the productivity of the new lands, meet with the difficulties which bear down on the individual and often even arouse antagonisms which are social and political.

Every one seems willing to conserve anything save only that upon which his daily bread and immediate future to him seems most to rest. The needs of the individual and of the family are real and important. Those of society and the nation are more indistinctly real to the individual, though they are none the less real and eternally necessary to society.

The individual longs for health, but, when diseased with an infectious disease, is apt to rebel when placed under the restrictions of quarantine, for that, in part, lessens or curtails his hope of gaining an immediate livelihood for himself and family. The farmer places his available funds and labors into new lands, which to him represent his immediate source of supplies, and instinctively must exert every effort to exploit and develop those resources upon which he depends in what to him appears to be the most effective manner to serve his immediate wants. Thus arises the desire to crop rapidly and largely, if not well. This view of the case, considered calmly, is very apt to place each of us in a better attitude towards helping the individual farmer in his struggle with cropping conditions. It is easy to say, "Oh, the farmers are an ignorant lot." "They sow one crop continually on the same land." "They do not rotate." "They do not make proper use of available fertilizers, suitable for plant growth," etc., but there are few members of this congress who do not realize that the science of cropping is not yet a very definite one, and if it were, and we should expect each farmer to understand it for the five or six necessary crops to be grown on his land, that we are asking him to understand principles of far more delicate and scientific nature than could now be expected of the lawyer, doctor, banker or other professional man.

We must also realize that many theories of agriculture which are by us recognized as correct in principle quite often fail to give results in practise. It thus behooves us as investigators to search for details which will explain many of the contradictory results obtained in our general cropping methods. *That the methods of the individual farmer are quite generally opposed to the real needs of society, and are often greatly to his own disadvantage, I believe gives the real foundation for the true doctrines of soil conservation and*

makes it clear that the true and safe route for the conservation of the natural resources of the soil rests in proper enlightenment as to the nature of the resources concerned and of the nature of the first causes which tend to destroy or cause deterioration in them. It is better to educate in cleanliness of person and premises than to set up quarantine against infection. It is better through force of education, or if necessary through education by lawful procedure, to force or bring about the cleaning up of underbrush in the spring than to have to fight destructive forest fires in August, or to waste time scolding corporations who as individuals do not know a sick tree from a ripe one. *Prevention is the most effective force whether we think of controlling criminals or of amelioration of crops.* So it is that our province as educators, especially with reference to conservation of the cropping powers of the land, is to so go into detail of explanation and demonstration of the causes of improvement or deterioration in crops that the individual farmer shall be able to understand the processes which are really necessary for his welfare, showing each worker wherein his methods are really effective in satisfying his needs, and wherein detrimental, both to himself and to society. If our methods of conserving the crop-producing powers of the soil are to be accepted, we must show that the methods proposed meet the needs of the individual farmer as well as of posterity so clearly that he can not be confused. If we can do this each individual worker will at once become an enthusiastic soil conservationist. If we can not do this, we can not expect it. Even then greed may make social criminals of some whose work is dependent upon the farmer, but the number of such will lessen rapidly under the educational forces of properly constructed laws. Even though seed dealers know that poor qualities of diseased seed and seed of mixed variety are very destructive to the interests of the farmer, and hence directly destructive to their own interests, yet most so-called seedsmen handle seeds much as a lumber yard handles coal or wood. Then there is the elevator man whose whole business interests are wrapped up in the successes of the work of the cereal crop producers, who yet buys seed from several farmers, mixes and spoils the whole lot, then sells it back to a new lot of farmers, making good returns from each transaction. Knowing this, one can understand why it is difficult for an individual operator or a number of them in cooperation to appreciate the point that it would be to their direct interest to sell, if they are to sell seed at all, only seed of reasonably pure, unmixed type. In both of which cases a well-worded seed law properly administered should prove of great benefit to all concerned and effectively educational.

The unnecessary waste in the exploitation of our mines and the rapid despoilation of the forest resources has aroused the nation, the work on the forests especially, because trees are big and beautiful and noticeably necessary to the very life of our nation, and the damage done to society by their destruction is at once apparent. Further, those of us who know the great value of phosphates in the production of seed grain can hardly do less than lament the rapidity with which these beds of valuable material are being mined and shipped abroad at but a trifle of their real value to the nation. We deplore this sort of loss because readily observable, but the same sort of greed for temporary gain in association with ignorance is depleting many other natural resources, among which most notable and far reaching is the first rapid depletion of the cereal crop producing ca-

pacity of the virgin soils, *through unsanitary methods of handling the soil, the crop and the seed.* It may be a comparatively new thought, but as I see it, there is no one factor affecting cropping results to so great loss of national wealth as the disease factor in the soil, and no one feature of cereal agriculture is so poorly understood and so much neglected. It is becoming common to term the farmer, and especially those who are farming in a large way "soil robbers." This is perhaps all right if we wish to shock them so that they may take notice while we call their attention to methods by which, if they follow them they may better their results and escape unjust criticism. But not all such men are intentionally "soil robbers." I have had the opportunity of meeting many wheat raisers, cereal croppers, who to my knowledge have more or less constantly followed the best advice available in cropping methods, at times with success and at times with indifferent success. Many are ignorantly soil spoilers and "crop deteriorators." It is to this phase of crop deterioration by soil contamination rather than to chemical depletion that I wish to especially call attention.

I recommend both our trained agriculturists and the farmer to look for help from a careful consideration of soil sanitation or, if you will, from proper conservation of the purity of the soil. I consider it particularly important that this question should be brought before this congress, for this meeting is located at a point west of the center of the last great virgin soil areas of this country. And because, while I recognize the great good that is done by the advocates of the conservation of the chemical qualities of the soil and still remain a strong advocate of the importance of that feature, I feel that we have followed it so persistently as to lose sight of other features which have vitiated many of the conclusions which have been drawn. When soil fertility is removed by persistent or constant cropping there must be some means provided for a reasonable replacing of the same; and crop rotation, as such, has been proved to be a matter essential to cereal agriculture. I believe, however, that the emphasis as to the cause of the necessity of crop rotation has not always been placed wholly in the right place. We have paid too little attention to physical or mechanical texture of the soil and too slight attention to cultivation methods as such, and no attention whatever to the sanitary condition of the soil. We have continued to tell the farmer that he must rotate because his methods of cropping are removing the nitrogen, humus and other essential features of the soil, apparently forgetting, although we all know, that a rotation is only another way of getting more of these elements out of the ground. We all agree in recommending stock as essential, apparently forgetting, although we all know, that that too is a condensed manner of getting rid of the so-called fertility of the soil.

So, if it had not been for the biologist demonstrating that the experience of many farmers in replenishing soil nitrogen through the use of legumes is a fact of plant life possible of intelligent control, our theories of crop rotation would at this time be in a sorry plight indeed, so far as proving the worth of them from a chemical standpoint alone. However, this problem of the conservation of nitrogen is now a settled one so far as common knowledge is concerned, and even the question of the conservation of the phosphates may rest in nothing more than the problem of equitable distribution of the world's supply. These fertilizers are based on substances that can not well get away. Though fertilizer experiments are as old as agricul-

ture and have been for the last century most carefully and elaborately planned, the best that we can say for the use of artificial fertilizers is that, as agriculturists, we are agreed that if we know the chemical make up of a particular soil it is possible to considerably enhance the cereal crop. However, regardless of all the extensive experiments, I think you will agree with me that it is not possible to state a plan purely of the nature of soil fertilization that will hold with any regularity as to the results on the crop for any extended area of soil for any long period of years. This is saying that the fertilizer question itself largely remains an experiment in spite of our best effort and that each farmer must largely learn what to do for himself, which is expecting much.

It is evident from studying the best and most extensive of these various fertilizer experiments that aside from soil texture and aside from differences in climate and variation in atmospheric conditions during different seasons there have been other unknown causes which have largely vitiated conclusions which may be drawn. This is equally true as to conclusions which may be drawn from long lines of carefully planned crop rotation experiments. It is one of these constant interfering influences which I wish to bring to your consideration, namely, the introduction of parasitic organisms which persist in the soil and seed, eventually bringing about soil sickness, such as has been recognized for cotton, melons, potatoes and many garden vegetables, alfalfa, clover and for flax. After extended experience with cereal crops of North Dakota and a rather close observation of them in various parts of this country, and of Europe, and from carefully conducted experiments extending over a period of twenty years directed upon the soil and the crop, I am convinced that such parasitic interferences with crop productivity constitutes one of the chief causes of the deterioration in quality and of yields of wheat, oats, barley and flax. Further, I would affirm, recognizing as I do that it is possible to so crop the soil as to withdraw chemical elements necessary to a complete normal yield, that, in most cases, especially in the northwest, this has not been done with regard to cereal crops, and particularly is this true of practically the entire area for Minnesota and the Dakotas. I know that the chemists and agriculturists have reasoned, from field tests with fertilizers and from laboratory analyses upon soil and seed, that chemical depletion of the soil is the chief cause of such deterioration, but my experiments make it impossible for me to accept the conclusion. There are areas of North Dakota virgin soil, represented by our school lands which yet remain unplowed, surrounded by old wheat areas which have been cropped for a number of years. These virgin lands when broken do not now, as when the prairies were first broken, produce wheat of number one quality, but often wheat of even lower grade and quality than that of the old lands immediately adjacent.

I know that in farmers' institutes in the various cereal-producing states, many farmers have said something to the effect that there must be a "change in climate," complaining that they no longer are able to produce wheat of the quality once produced, although they now work the land much more carefully, having better machinery. Some of them practise essentially all of the doctrines of the experiment stations and farmers' institute workers, and yet reap only low-grade grain for their trouble. I know that these questions have usually been answered by saying, "You can not expect to continue reaping grain of high quality." "Your constant meth-

ods of cropping have deteriorated your soil." The questions usually run, "What has happened to the soil?" "You have lessened the nitrogen." "You have changed the humus condition," or "You have withdrawn too much phosphates or potash," etc., as the case may be. The question then arises, "What shall we do?" The answer: "Rotate." "Raise stock." "Plant corn." "Cultivate." "Clear your fields from weeds." "Select seed." Yet many able farmers who are doing all these things reap 12½ to 15 bushels of shrivelled wheat where once they took 25 bushels to 30 bushels of 60- to 62-pound stuff. Such men tend to lose faith in our doctrine of conservation of the fertility of the soil and our doctrines of the necessity for crop rotation. Often the best rotation gives the most shrivelled grain and then, we as educators have been utterly at a loss to explain the cause unless we could attribute it to smut or rust, drought, rain, sunscald, etc. Indeed there are many Red River Valley farmers who will agree with me that when climatic conditions and soil conditions and harvesting conditions have been most propitious for the development of the wheat crop, often the yield has been of the most inferior type of seed. Though the bushels of grain and the tons of straw may be somewhat larger, the quality is so inferior as to be no longer in the class for which the northwestern wheat regions were once noted.

I am glad, gentlemen of the congress, that I am not only able to call your attention to these facts, which I think you recognize as not overdrawn, but that I can name the causes so that any one of you who wishes to investigate can verify. Our older wheat soils are sick throughout or sick in large areas in exactly the same sense as certain cotton lands are sick with root-rots, in the same sense as certain melon lands produce root-rot and blight, in the same sense as old potato lands which produce rot and scab, and in the same sense as the Germans recognized, when they spoke of flax being a bad crop to raise because it produced "Bodenmuedigkeit," "flax-sick" conditions. I am now able to recognize such wheat-sick areas and map them as well as I could four or five years ago for the flax-wilt disease. This mapping of the sick areas can be done any time from the time the wheat plants first come out of the ground to the time the stubble is plowed in the fall. How many distinct parasitic organisms it takes to make a typical wheat-sick soil we can not yet affirm, but our experiments are sufficiently extensive for us to state that at least five such parasites are persistent internally in most seed wheat, parasites which enter the seed before it is mature and are carried over to the next generation, and which are also, when once introduced into the soil, persistent there for a number of years following the introduction, and which, according to variable weather conditions, methods of handling the soil, variation in the fertilization of the soil, etc., are able to do a greater or less amount of damage. They are so truly parasitic in structure that they persist in their destructive work in any type of soil and in any type of atmospheric conditions in which the wheat plant can really survive. They are so saprophytic in habits that they fruit freely on decaying roots and stubble, and thus are readily distributed from crop to crop and from field to field. They are so parasitic that through their connection with the seed their distribution is made easy from field to field and from country to country, and I have found few samples of durum wheat and few samples of hard wheats or soft wheats, winter wheats, ryes or barleys that one or all of these wheat-destroying

parasites may not be obtained from the seed. Our survey covers every county in North Dakota and extends into Alberta and the wheat fields of Manitoba, Minnesota, South Dakota, Washington and California and the winter wheat regions of Indiana, Kentucky, New York and the wheat regions of Ontario. The parasites have been found in seeds imported from Russia, Italy, France and Algiers, and have been taken from samples of straw and roots from almost every important wheat area of Minnesota or North Dakota. I am thus confident that I am not announcing a crop destruction feature of local nature.

It is beyond the possibilities of this paper to detail the various lines of experiments by which these conclusions have been made necessary, but I may state that the three most destructive parasites, taken in their order, are one or more species of *Helminthosporium,* one or more species of *Fusarium,* the type of fungus which produces wheat scab and flax-wilt, and one or more species of *Colletotrichum.* These are universal and effective on roots and leaves, stems and seed, and various species of *Macrosporium* and *Alternaria* are great blighters of seed and destructive both on the straw and on the grain, especially at germination time. Our experiments have gone so far that I may say that I can take any type of soil in North Dakota and Minnesota which will grow the hard spring wheats and from it raise either a typically diseased crop or plants of normal growth. The methods of doing this are too expensive for farm operations. They consist essentially in soil and seed sterilization, whether it is done by chemicals or by heat. We have conducted persistent cropping experiments for many different pure pedigreed strains of wheat upon twenty-seven separate fertilizer plots, the strains of seed for all plots being the same at the beginning of the experiment, after which each plot has raised its own seed. These fertilizer experiments demonstrate clearly that in the absence of knowledge of the presence of the diseases no one could draw any reliable conclusion as to what crop they might cause to develop in any particular year. They do, however, demonstrate that various types of fertilizers have more or less effect upon the development of the diseases and of the crop, and that the mechanical condition of the soil has much to do with the development of both crop and diseases, and that whenever there is a tendency to check the development of the disease in the straw there is a tendency to produce plump seed. For example, the addition of phosphates does not seem to do away with the actual presence of the parasites in the soil, but it does enable the straw to ripen plump seed. The proper conclusion is not that the soil is necessarily deficient of phosphates, but that, the soil being infested with parasitic fungi, the addition of more phosphates tends to harden the straw in the same sense that a harsh dry atmosphere, such as some of you people are interested in, and such as North Dakota has suffered intensely from during the past season, tends to harden the straw and make plump wheat, though it does not of necessity mean a large number of bushels. I have this season seen fields that were so diseased with these root parasites that, in association with the drought, the wheat did not grow high enough to reach the sickle bar, and yet there was plump wheat from such sick plants. Whenever such sick areas received a reasonable shower or the soil was so cultivated as to conserve the moisture, there was an increase of bushels and a decrease of quality, due to shrivelling of the grains. The fungi are so constituted that they appreciate a highly vegetative type of straw, and when there is

an overbalanced supply of nitrogen plus moisture, they readily destroy such straw and the grain is proportionally shrivelled. They penetrate such straws rapidly and reach the seed at blossoming time and it is cut off from the mother plant and can not mature, even though in the straw there is left much unorganized plant food. Just in proportion as the fungi are capable of penetrating the straw the seed is deteriorated. Straws will crinkle and fall down when attacked by these diseases in a manner very characteristic of crops on over-fertile or over-worked soils, even though there is a deficiency of moisture and of soil fertility, while the same pedigree of seed will stand strong and sturdy upon soil of much richer character with reference to nitrogen and still produce plump seed in the absence of the fungi. These fungi are so common and persistent in their nature in the soils of the northwest that if any one of you will go out into the stubble of an ordinary field where the wheat grains were evenly distributed in the drill row and of proper thickness of planting, and if you find that a part of the plants stool well and a large percentage of them produce only single straws of more or less weakness and smallness of diameter, I can assure you that you will find the roots of those unstooled plants in a diseased condition, whether you pull them before heading or after the grain is cut (usually black-footed, creosote colored or gray to mouldy). Exceptions are so few as to prove the rule. These diseases are of such nature as to largely account for the off grades in grain, for I have found in wheat plants which are sufficiently affected for the parasites to reach the seed that the grain will be off color, and will be graded by the elevator men as bleached and blistered, "black-pointed," "white-bellied," etc., even though cured under canvas and having suffered from no moisture effects whatever, either before or immediately following harvest.

One, and perhaps two, of the most destructive of these parasites produce the effects known as black point in durum wheat, a disease which is very prominent and becoming much more common of late years than when the grain was first imported into this country. Durum wheats, because of their peculiarity of straw, are able to produce plump wheat and yet carry diseases inside to such extent that 15 to 25 per cent. of properly harvested and cured wheat will not germinate. These diseases, especially the *Fusarium* type, largely account for the low germination of durum wheats. This I have proven both by culture work and by infection. The *Fusarium* diseases and possibly alternarial diseases largely account for the so-called "piebald" wheat or "white-bellied" wheat. I have previously claimed that moisture after the formation or maturity of the berry was the chief cause of this trouble. Others, notably Professor Shutt, of Ontario, claim that the loss of humus and nitrogen, causing a fall in the proteid content of the berry, is the cause, but I find that with the presence of certain fungi and a certain amount of moisture the result is almost certain, while in the absence of the fungi and moisture there is no piebald wheat, regardless of the nitrogen content of the soil.

All of these types of diseased grain breed true, that is, a diseased grain will carry the diseases to the soil, and if the seed can germinate and the young wheat plant can survive to the extent of producing seed, and the weather conditions are just right for the growth of wheat, the disease will be manifested in the seed of the progeny, and will persist in the soil so as to attack the following crop of wheat.

There are other features of marked interest which explain many of the common observations of cereal cropping. I can note only a few of these which might amount to an explanation of difficulties met with in our efforts at crop betterment and of the benefits which accrue from those methods which are recognized.

Farmers have noticed that where fresh barnyard manures have been spread upon their soils preceding wheat, a comparatively small amount has resulted in what they have called over fertility. My observations and experiments show that this is not necessarily over fertility, but increased soil infection coming from the excess of fungi due to cultures developed in the old straw and manure made from bedding straw drawn from diseased fields. Such straw introduced on the newest land immediately results in the production of shrivelled grain and in general crop deterioration in following years. In the case of flax my own experiments have been many times confirmed by the farmers. If barnyard manures which have been made by stock fed or bedded with flax straw are used, the soil may be ruined for the growth of flax by one application, even though no flax has ever been grown there before. This applies equally to wheat, barley and oats, when bedding made from sick straw of such crops is used, though apparently not so markedly destructive because of the fibrous method of rooting of these cereals.

We have all observed and advocated that the best possible preparation of a soil for the production of either wheat or flax is that which comes from a properly cultivated corn field, which is not again plowed before the grain is seeded, but which receives only shallow or surface cultivation. We have all observed that the expected better yields do not always follow, and that instead of getting plump wheat or good flax there may be much wilt in the flax or the wheat may not produce the big yield of plump grains. This in cases of wheat is analogous with the results on new lands, previously cited. There are two reasons why we may not of necessity expect better results on the corn crop ground. If that be a small piece of ground surrounded by old wheat stubble lands, the drifting or blowing of the diseases from these lands throughout the season may readily keep the corn ground thoroughly infected, while the cultivation sets free a larger and more available food supply and the crop grows ranker and more succulent, only to be destroyed by its parasitic enemies. If the field be sufficiently large so as not to be thus injured by the surrounding areas, or if there are no surrounding areas, the labor on that new well-worked land may be largely lost by the use of infected seed taken from old lands.

It is a well-known fact that quack-grass (*Agropyron repens*) is the most destructive weed known to cereal agriculture. It has been a wonder to most farmers and many experimenters why wheat is able to make so little progress against this weed even after the greatest efforts are made to prepare the seed bed. Usually we have assumed that the heavy rooting capacity of the quack-grass allows it to rapidly take charge of the ground, exhaust the moisture and thus overcome the cereals seeded over the quack-grass area. Our late observations and cross inoculations convince us that the quack-grass has a great advantage over the cultivated wheat. Not uncommonly the roots of the quack-grass, and especially the heavy underground stocks, are thoroughly attacked by several of these wheat-destroying diseases which fruit freely upon the dead and dying underground masses of quack-grass. The young wheat plants placed over such a center of

diseased material can have little opportunity to develop, being immediately attacked by the diseases and placed in competition with a much more vigorous plant.

The power of such parasitic diseases and of such soil infection is illustrated in the case of numerous garden crops, such as potatoes with potato scab, and cabbage with root-rot, asters with yellows or blight, but it is far more destructive on the field crops which produce seed than upon such heavy rooting plants. The history of the flax crop and its apparent necessary relation to new lands well illustrates the point. Few people believe the flax crop possible of success in any other than approximately virgin soils. Only in the Netherlands under the most intensive farming has the flax crop remained a permanent one. In all other countries it is essentially a new land crop. One, two, three or four paying crops have been removed from new land and then the grower has ceased to handle the crop, whether or not he wished, as the yield no longer payed expenses on the work.

These should be interesting facts to western farmers who dislike to see one valuable crop in our rotation disappear, and especially to know that during the last ten years the center of flax seed production has moved over 200 miles to the west. Interesting not because it is coming your way but because it is going. Even the transitory tow mills can not keep up with the chase. Statistics prove that there is no exception to the rule so far as the growth of flax seed is concerned. It is difficult to compile statistics from those available to show these facts, for, during the past ten years, the actual output of seed has tended to increase in North Dakota as a whole. It is only when we visit a shipping point and notice the land areas from which crop is no longer taken and those from which the seed is now coming that we know the truth of the matter. While a particular shipping point may yet be sending out more flax seed than it did ten years ago, we find that the source of the seed is from new lands, and that the farmers are hauling it longer distances to the shipping point. However, many of the older points in the state well illustrate this feature when contrasted with the newer shipping stations. Thus, for example, in 1902 the eastern town of Buffalo shipped 1,326 tons, while in 1909 the shipment from the same elevators was 520 tons. The new town of Richardton shipped a few bushels of flax seed in 1905 and in 1909 was shipping 814 tons of seed. Leeds in 1902 handled 5,075 tons of flax seed from one of its two lines of railway elevators, while the same set of elevators in 1909 handled only 120 tons of seed in contrast with Beach, a new station opened up for flax seed shipment in 1905, which handled 11,210 tons of seed in 1909. Devils Lake, Larimore, Cummings, Wahpeton, Landon, all originally great shipping points for flax seed in the eastern part of North Dakota, show records of practically no tonnage in 1909, while small towns such as Page, Hope, Stephen, surrounded by new lands, show shipments in 1909 exceeding 1,000 tons each. This is but the story of the transient nature of the flax crop as it now stands. The story not of its disappearance by lost fertility, but through disease infection of the soil.

It is interesting to know that many farmers have verified our conclusions that this disappearance of the crop is essentially unnecessary. Proper seed selection and seed disinfection associated with crop rotation will place the yield of flax seed always upon a profitable basis, the yield being considerably greater than anything that could be originally obtained.

This brings me to the real point of my

paper, namely, that we have a problem of soil sanitation which is far greater in its bearings upon the world's food supply and upon the principles of cereal cropping than any of the most enthusiastic plant pathologists or any of the most able agronomists have ever anticipated. If I am right in the conclusions which I have here set forth, then we have a doctrine of hope for cereal agriculture rather than one of despair. I have outlined causes which account for many of the anomalies in the best conducted experiments in crop rotation and soil fertilization, and have indicated bearings and influences which are now more easily understood.

If into your schoolroom, with its many children, there should come a patient afflicted with infantile paralysis, or one with diphtheria, or one with small-pox, each of you would be thoroughly frightened. You may not have seen anything, but you have learned to believe the doctor when he says that the symptoms exhibited by these patients are characteristic of infectious troubles and you say to the health officer, "This building must be closed and disinfected." Why? Because you know, if you do not do so, that, however healthy and strong the children sent there may be, there will be some who suffer great misery; some that are marked for life, some that are paralyzed and not a few who die.

So it is with cereal cropping. Large areas of the world's wheat fields are not depleted chemically, but rather contaminated with many of the diseases that wheat is heir to, and a number of these diseases are transmissible in nearly related crops. In saying this I am placing before you an argument for crop rotation which any one of you can understand and such as any farmer can understand without the discouraging thought that he has, because of his ignorance, in a few short years, in some cases one, two or three, destroyed his land by the removal of chemical elements. We all believe in crop rotation. Here is one of the reasons why it succeeds and a clear explanation why a properly planned series may fail. We believe in the conserving of fertility of the soil by the application of manure, and herein we have a clear explanation of the reasons why the application of manures sometimes is thoroughly destructive, and why under certain conditions it need not be destructive, why it is, for instance, that the processes of composting and the use of liquid manures by old-time gardeners and farmers do not go out of existence, regardless of the theories of those who wish to sell the manure spreader.

I am not an enemy of the manure spreader. It is a great labor-saving device, but I wish to say that unless it is used more intelligently than has usually been advocated in the northwest it may be placed as one of the most destructive agents now in use in cereal cropping through weed seed and disease dissemination. The manure spreader would still be a useful instrument if proper types of manure were spread on the right crop. We are all believers that heavy weight seed is more effective in crop production than light weight seed of the same pedigree. That has been pretty hard for one who believes in pedigree to understand; for the small amount of food which a parent seed can give the young plant, in most cases, is merely a start in the world. Here is the real explanation of the fact.

Those of us who have been directly interested in the disinfection of cereal grains for planting purposes have long since become convinced that proper seed disinfection greatly enhances the crop yield, even though the seed be number one, hard in quality, and though there be no smut

spores present for which disinfection was originally brought out. In North Dakota I have found that on the basis of a twenty bushel yield, number one hard seed, free from smut, disinfected with formaldehyde, may be expected to give, when planted on the same soil on the same day, from one and a half to four bushels per acre more than the same wheat not disinfected. For years I could not explain this any more than to say, "It is possible that formaldehyde may act as a stimulant to the young plant, or that it is possible that it may destroy other fungi such as bacteria, yeasts and moulds, etc. I now know that the spores of these soil and root diseases may often be present on the exterior of such seed, and thus we have a clear explanation and reason why all seed should be disinfected every year, regardless of the presence or absence of smut.

As previously indicated, the idea of conserving the fertility of the soil seems to be as old as agriculture, but the study of the soils from the standpoint of the health of the cropping plant as viewed from physical and mechanical texture and its disease-bearing features, are matters which have had much too slight attention. Overlooking them, we have not been able to explain the conflicting results obtained by our best theories or methods of cropping. We have had our thoughts centered on the possible loss or depletion of fertility and upon the possible unbalancing of the food ratio as represented in eleven to fourteen chemical elements, and although we have known well that a plant can use up essentially every bit of an available plant food before deterioration becomes apparent in its growth qualities, we have blindly assumed that many soils which from their texture and age should be thoroughly fertile, are nevertheless depleted in their food supply. We have paid too little attention to the life of the plant itself and to biological features connected therewith, and to the needs of adapting our cultivation methods to the actual physiological processes of the plant that it may not sicken and become so weak as to fall an easy prey to its enemies.

Just at this point, I may say that these root diseases are of such nature, whether we speak of flax or wheat, that certain varieties and strains of the crops may be recognized as markedly resistant, and that even the common crop may resist to such extent as to produce a reasonable yield on a normal year. Yet through any untoward condition, such as the bites of insects, or injuries due to dry air coming in contact with the roots in a loosely prepared seed bed, or due to the weakening effects of poor drainage, the individual plants and the average of the crop may fall a ready prey to the disease-producing organisms. These organisms are not only parasites in their ability to attack young growing plants, but they are rather more saprophytes than parasites in the sense that whenever a plant tends to sicken and die they readily attack and overcome it, so that poor drainage and drought, heat, frost and insect depredations, greatly facilitate the destruction occasioned.

It is my belief that these soil and seed diseases, especially of wheat, flax and oats, have broken many a hope for a large crop, and have vitiated the conclusions drawn from many well-planned schemes of cropping.

What has this to do with the dry land farming? As previously indicated, there are great areas of this country that have been contaminated with cereal diseases. The methods of constant cropping, careless selection of seed, lack of seed disinfection, and the lack of proper preparation of the seed bed so as to properly firm it down and thus insure that the fine roots shall

always be in contact with sufficient moisture to allow them to make a normal, sturdy growth, have gone on in such a careless manner as to greatly reduce the wheat yields of all countries wherever such cropping has been practised upon a large scale such as is known in the new lands of the northwest. Where this contamination of soil has occurred the loss of the flax crop has been unavoidable, and profitable wheat raising has only been continued under intensified farming conditions. My belief is that we must yet be able to produce the bread of the world by the use of extensive machinery and upon extensive plans, such as is yet being carried on in the new lands of the west. I have set forth *the reasons why this can not be done unless we recognize this question of soil sanitation,* or, if you will, *the necessity of conserving the virgin purity of the land.* I am, however, confident that with the proper understanding of the methods which are now known for selecting seed, disinfecting seed, rotating crops and perfecting the seed bed there should be no necessity of growing wheat upon the costly lands now under intensified farming systems, and that there is no immediate necessity of abandoning the cropping to cereals on the large plan which is characteristic of the northwest. I believe firmly, however, if we do not thus recognize this matter of the necessity of soil sanitation, soil disinfection by means of proper cultivation, and well-planned series of crop rotation, that, no matter how fertile the soil of one of your western valleys may be, no distant year will see your crop fall very close to the world average for that particular cereal.

This message, if so it may be called, has also a direct bearing upon matters in which you are interested which I think you will thoroughly appreciate. Those of you who are directly interested in dry land farming may expect these diseases to be less effective under dry farming conditions than under the old-line cropping methods. For the dry farming methods and the dry atmospheric conditions are just such as tend to keep such cereal organisms in best control. If, however, you wilfully spread diseases upon your lands through infected seed and through infected fresh, uncomposted manures, if you wilfully neglect to rotate and if you fail to properly aerate and firm down the seed bed, you may expect these destructive cereal diseases to take their annual quota from your crop, and that the crop depletion will increase with the years. There seems to be no exception to the common observation that the living can not thrive in contact with the dead of the same species.

If, on the other hand, you declare for careful seed selection in all cases, careful seed disinfection at all times, the formation of a well-aerated but compacted seed bed, and for as extensive a rotation of crops of as wide-spread character as possible, you of the new dry land regions of the west have the greatest possible opportunity to prove to the world that it is not necessary to lose a crop of such importance as linseed from among your rotations, nor is it necessary that your wheat yields should fall from the now promising ones of thirty to sixty bushels per acre to the general average of twelve to fifteen.

H. L. BOLLEY

NORTH DAKOTA AGRICULTURAL COLLEGE,
September 20, 1910

THE FOURTH CONFERENCE OF THE INTERNATIONAL UNION FOR COOPERATION IN SOLAR RESEARCH

THE main party of delegates to the fourth Conference of the International Union for Cooperation in Solar Research arrived in Pasadena on August 28. On the following